05-R-320, Linac Coherent Light Source, Stanford Linear Accelerator Center, Menlo Park, California

(Changes from FY 2005 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

The scope of work in FY 2005 has been expanded to include modification of existing facilities at the Stanford Linear Accelerator Center for testing of the long-lead equipment items.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost[a] ($000)	Total Project Cost[a] ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2005 Budget Request *(Preliminary Estimate)*.................	2Q 2003	4Q 2006	1Q2006	4Q2008	260,000	315,000
FY 2006 Budget Request *(Performance Baseline)*...............	2Q 2003	4Q 2006	3Q2006	2Q2009	315,000	379,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering Design			
2003	5,925 [b]	5,925 [b]	3,644
2004	7,456 [b]	7,456 [b]	9,670
2005	19,914 [b]	19,914 [b]	17,664
2006	2,544 [b]	2,544 [b]	4,861
2007	161 [b]	161 [b]	161
Construction			
2005	29,760[cd]	29,760[cd]	25,280
2006	83,000	83,000	78,625
2007	105,740[d]	105,740[d]	99,800
2008	50,500	50,500	62,320
2009	10,000	10,000	12,975

[a] The full project TEC and TPC, established at Critical Design 2b (Approved Performance Baseline), are $315,000,000 and $379,000,000, respectively.
[b] PED funding was reduced by $75,000 as a result of the FY 2003 general reduction and rescission, by $44,000 as a result of the FY 2004 rescission, and by $161,000 as a result of the FY 2005 rescission. This total reduction is restored in FY 2005, FY 2006, and FY 2007 to maintain the TEC and project scope.
[c] FY 2005 funding in FY 2005 President's Request was for long-lead procurements. The scope of work in FY 2005 has been expanded to include modification of existing facilities at the Stanford Linear Accelerator Center for testing of the long-lead equipment items.
[d] Construction funding was reduced by $240,000 as a result of the FY 2005 rescission. This total reduction is restored in FY 2007 to maintain the TEC and project scope.

3. Project Description, Justification and Scope

The purpose of the Linac Coherent Light Source (LCLS) Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray Free Electron Laser (FEL) in the 1.5 - 15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems described below. This will be the world's first such facility.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 GeV for colliding beam experiments and for nuclear and high-energy physics experiments on fixed targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into PEP-II, and the entire linac is used for fixed target experiments. When the LCLS is completed, the latter activity will be limited to 25 percent of the available beam time and the last one-third of the linac will be available for the LCLS a minimum of 75 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5 - 15 GeV electron bunches at a 120 Hertz repetition rate. When traveling through the new 120 meter long LCLS undulator, these electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent x-ray beam for scientific research.

The LCLS makes use of technologies developed for SLAC and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radiofrequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of x-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current x-ray sources (both synchrotron radiation light sources and so-called "table-top" x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser-like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing 10^{11} x-ray photons in a pulse with duration of less than 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific application in the chemical, material, and biological sciences.

The LCLS Project requires a 135 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one-third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new undulator and associated equipment. Two new buildings, the Near Experimental Hall and the Far Experimental Hall, will be constructed and connected by the beam line tunnel. A Central Laboratory and Office Building will be constructed to provide laboratory and office space for LCLS users and serve as a center of excellence for basic research in x-ray physics and ultrafast science.

The combined characteristics (spectral content, peak power, pulse duration, and coherence) of the LCLS beam are far beyond those of existing light sources. The demands placed on the x-ray instrumentation and optics required for scientific experiments with the LCLS are unprecedented. The LCLS experimental program will commence with: measurements of the x-ray beam characteristics and tests of the capabilities of x-ray optics; instrumentation; and techniques required for full exploitation of the scientific potential of the facility. For this reason, the project scope includes a comprehensive suite of instrumentation for characterization of the x-ray beam and for early experiments in atomic, molecular, and optical physics. The experiments include x-ray multiphoton processes with isolated atoms, simple molecules, and clusters. Also included in the scope of the LCLS Project are the instrumentation and infrastructure necessary to support research at the LCLS, such as experiment hutches and associated interlock systems; computers for data collection and data analysis; devices for attenuation and collimation of the x-ray beam; prototype optics for manipulation of the intense x-ray beam; and synchronized pump lasers.

Beyond the scope of the LCLS construction project, an instrument development program has been implemented in order to qualify and provide instruments for the LCLS. Instrument proposals will undergo a scientific peer review process to evaluate technical merit; those concepts that are accepted may then establish interface agreements with the LCLS Project. Expected funding sources include appropriated funds through the Department of Energy and other Federal agencies, private industry, and foreign entities. These instruments will all be delivered after completion of the LCLS line item project. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, has already identified a number of high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. Five specific areas of experimentation are: fundamental studies of the interaction of intense x-ray pulses with simple atomic systems; use of LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter. The combination of extreme brightness and short pulse length will make it possible to follow dynamical processes in chemistry and condensed matter physics in real time. It may also enable the determination of the structure of single biomolecules or small nanocrystals using only the diffraction pattern from a single moiety. This application has great potential in structural biology, particularly for important systems, such as membrane proteins, which are virtually uncharacterized by x-ray crystallography because they are nearly impossible to crystallize. Instrument teams will form to propose instruments to address these and other scientific areas of inquiry.

Construction funding requested in FY 2005 is for selected long-lead items, and the necessary refurbishment of existing space to provide for a magnet measurement facility for the testing of the long-lead equipment. Early acquisition of selected critical path items will support pivotal schedule and technical aspects of the project. These include acquisition of the 135 MeV injector linac, acquisition of the undulator modules and the measurement system needed for verification of undulator performance, and acquisition of main linac magnets and radiofrequency systems required to produce electron beams meeting the stringent requirements of the LCLS FEL. Early acquisition of the 135 MeV injector is required in order that first tests of the FEL can begin. Acquisition of the undulators in FY 2005 will allow delivery in FY 2007, which in turn will enable achievement of performance goals in FY 2009. The main linac magnets and radiofrequency systems must be ready for operation shortly after the linac has reached its performance goals.

The FY 2006 funding is requested to initiate physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Central Laboratory and Office Building. In addition, the injector will be completed and construction of the downstream linac and electron beam transport to the undulator hall will begin. Undulator module assembly will be started along with construction of x-ray transport/optics/diagnostics systems.

4. Details of Cost Estimate

	(dollars in thousands) Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	18,200	18,500
Design Management costs (1.6% of TEC)	5,000	5,000
Project Management costs (1.6% of TEC)	5,100	5,000
Total Design Costs	28,300	28,500
Construction Phase		
Improvements to Land	9,000	8,000
Buildings	54,100	36,300
Other Structures	6,600	1,800
Special Equipment	105,800	98,000
Inspection, design and project liaison, testing, checkout and acceptance	8,000	4,500
Construction Management (2.9% of TEC)	9,000	6,000
Project Management	15,700	11,700
Total, Construction Costs	208,200	166,300
Contingencies		
Design Phase (2.4% of TEC)	7,700	7,500
Long Lead Procurements (2.1% of TEC)	6,500	6,000
Construction Phase (20.4% of TEC)	64,300	51,700
Total, Contingencies (24.9% of TEC)	78,500	65,200
Total, Line Item Costs (TEC)	315,000	260,000

5. Method of Performance

A Conceptual Design Report (CDR) for the project has been completed and reviewed. Key design activities are being specified in the areas of the injector, undulator, x-ray optics and experimental halls to reduce schedule risk to the project and expedite the startup. Also, the LCLS management systems are being put in place and tested during the Project Engineering Design (PED) phase. These activities are managed by the LCLS Project Office at SLAC, with additional portions of the project being executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL). The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect (experimental halls, tunnel connecting the halls, and a Central Laboratory and Office Building) was contracted to an experienced Architect/Engineering (A/E) firm to perform Title I and II design. Title I design was completed in FY 2004. Title II design began in FY 2005.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2004	FY 2005	FY 2006	Outyears	Totals
Facility Cost						
PED	3,644	9,670	17,664	4,861	161	36,000
Long-Lead Procurements	0	0	25,280	4,720	0	30,000
Construction	0	0	0	73,905	175,095	249,000
Total, Line Item TEC	3,644	9,670	42,944	83,486	175,256	315,000
Other project costs						
Research & Development	0	1,750	4,250	0	0	6,000
Conceptual Design	1,470	0	0	0	0	1,470
NEPA documentation costs	30	0	0	0	0	30
Pre-operations	0	0	0	3,500	45,000	48,500
Spares	0	0	0	0	8,000	8,000
Total, Other Project Costs	1,500	1,750	4,250	3,500	53,000	64,000
Total Project Cost (TPC)	5,144	11,420	47,194	86,986	228,256	379,000

7. Related Annual Funding Requirements

(FY 2010 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs	$50,000	$50,000
Total related annual funding	$50,000	$50,000

FY 2010 is expected to be the first full year of LCLS facility operations. The current estimate is preliminary and based on historical experience with operating similar types and sizes of facilities. This estimate will be refined as the LCLS Project matures.

The estimate includes LCLS facility operations only. It does not include SLAC linac operations which is funded by HEP in FY 2005 and prior, but begins 3-4 year transition to BES funding beginning in FY 2006. Operation of the SLAC Linac is essential to the operation of the LCLS.